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Advances in the Search for Life

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It is no longer considered foolish to argue that biology could exist on some of the trillion other planets in our galaxy. Its discovery would produce a lasting change in our perceptions, demonstrating that life is not confined to our world. We would know that biology is not some sort of miracle, but a commonplace – an ubiquitous, cosmic infection.

The discovery of *intelligence* elsewhere would be of even greater import, as we have always considered humans to be special, even the pinnacle of Creation. To learn that there are others out there – others whose cognitive abilities exceed our own – would be a discovery that would recalibrate how our species views itself. It would also have consequences that can be only vaguely gauged, in much the way that the discovery of the New World led to societal changes that were largely unpredictable at the time of its happening.

However, the search for extraterrestrial intelligence, known by the acronym SETI, has been pursued for more than a half century with no unambiguous, positive result. We haven't found conclusive proof of any intelligent (or even unintelligent) life beyond the confines of Earth. Claims that our planet is being visited by alien beings, while popular with the citizenry, are not considered credible by most scientists.

However, recent developments in both astronomy and technology are accelerating the speed of SETI searches, and it is hardly fantastic to suggest that we could find evidence of cosmic company within a few decades.

The belief that life is commonplace

For most of recorded history, there has been optimism that the heavens are filled with other beings. This was true even during the time of the classical Greeks. But hypothesis eventually yielded to observation following the invention of the telescope. For four centuries, some of the best minds in what was called "natural philosophy" claimed to espy evidence for technically advanced inhabitants on the moon and Mars. None of this was true.

Today, we have both improved instruments and greater knowledge of the cosmos. While we no longer expect to find upright, sentient aliens in our solar system, we still hear claims of possible evidence for life. In 1996, researchers at NASA and Stanford University announced that they

had found fossilized microbes in a meteorite known to come from Mars. However, despite the fact that this was a major news item, most members of the astrobiology community regard this story with skepticism. Arguably, it has inclined most scientists to be cautious about announcing they have discovered life or intelligence elsewhere. But while claims are less common now, they have hardly disappeared.

As example, the dramatic changes in brightness of an object known as "Tabby's star," first found by NASA's Kepler space telescope two years ago, have been explained as conceivably due to the engineering efforts of sophisticated beings. While admitting that this is possible, most scientists think a completely natural explanation for the strange behavior of Tabby's star is more likely. Resolving this issue will be difficult, given the star's considerable distance (1500 light-years).

Tabby's star is a good example of the tendency by the public to interpret every puzzling astronomical discovery as possibly the consequence of intelligent activity. Fast Radio Bursters (FRB's), first observed approximately a decade ago, are short, enormously powerful flashes of light and radio waves coming from the sky. Roughly twenty FRB's have been seen, but their nature and workings are mysterious. Could they be alien signals? At least one has been traced to a galaxy several billion light-years distant, and if it is really due to extraterrestrial activity, then the society that produces it wields (or perhaps one should say, wielded) an energy source enormously beyond anything within our ken.

Despite the excitement of these deep space phenomena, as well as other new discoveries that might betray biology within our solar system (such as the intriguing ices being spewed into space from the Saturnian moon Enceladus), the fact remains that no certain evidence for life – dead or alive, microscopic or macroscopic – has ever been found.

Nonetheless, two high-ranking scientists at NASA have opined that we will trip across evidence for extraterrestrial biology within two decades. The present author has argued that a similar timescale applies to the detection of intelligence.

Why are researchers optimistic about the chances for discovering life so soon – even intelligent life?

One reason is the very recent evidence that planets and moons suitable for biology are bewilderingly common. One of the stunning conclusions from the data collected by the Kepler telescope is that the overwhelming majority of stars are orbited by planets. Indeed, we can now confidently state that there are roughly a trillion planets in the Milky Way galaxy, and the most common type are those that are comparable in size to the Earth. The Hubble telescope has shown us that two trillion *other* galaxies lie within the observable universe. Thus, the total number of planets within our purview is greater than the number of grains of dry sand on all Earth's beaches. The number of moons will be larger still, a fact of some importance, as moons are also possible habitats for life.

The inevitable implication of the above is that if biology is limited to Earth, then our planet is a miracle. Experience has cautioned scientists against ascribing observed phenomena to miracles.

Of course, an abundance of life does not necessarily imply an abundance of sentient life. Some biologists have argued that, while microbial life might, indeed, be widespread, intelligence could be exceedingly rare. However, given the daunting number of potential habitats, coupled with the fact that most stars are billions of years older than our Sun (allowing ample time for evolutionary processes to produce complex organisms), such pessimism seems unwarranted.

Searching for life

Leaving aside scientifically questionable claims that extraterrestrials are visiting Earth, there are three main schemes currently used for discovering extraterrestrial biology:

1. Find it *in situ* by, for example, sending robot spacecraft to investigate promising sites on Mars or gather samples from ice geysers that spray from two moons of Jupiter and Saturn. These are experiments that are possible for NASA or others to do in the coming decade.

2. Measure the secondary effects of biology in the atmospheres of nearby exoplanets (planets around other stars). The detection of abundant oxygen or methane could tip off researchers to the presence of biology on other worlds. NASA's new James Webb space telescope might be capable of making this type of measurement for the nearer exoplanets, as will very large, ground-based optical telescopes planned for operation within ten years (e.g., the Thirty Meter Telescope).

3. Detect radio or optical (visible light) signals from other star systems. Such signals would indicate the presence of technically accomplished inhabitants. This is the approach used by most SETI researchers.

We consider this third approach, and the search for intelligence, in what follows.

While the first SETI experiment was conducted nearly six decades ago, neither it nor any of its successors has captured a signal that has been confirmed as having an artificial, extraterrestrial origin. Despite this seemingly disappointing track record, it would be a mistake to ascribe this to a lack of prey. Because of the need to examine both a large number of stars, over a wide swath of the radio spectrum (generally at microwave frequencies, where the universe is relatively quiet), these experiments are slow. They go through their observing lists at a rate that's typically a handful of star systems each day.

To put that in context, if we conjecture that there are 100 thousand signaling societies in our galaxy, then we will have to scrutinize roughly one million star systems before detecting a transmission. This is approximately ten times the total sample of all SETI experiments undertaken since 1960.

However, thanks to rapid advances in computing technology, SETI experiments are becoming faster. In the past two decades, the receivers used for such work have improved to the point where they can instantaneously seek signals over many tens of millions of radio channels. In the next decade, this will become hundreds of millions, or even a billion.

This stunning advance in capability means that reconnaissance of the myriad star systems of the galaxy will become far faster, and within twenty years it's fully possible that the requisite examination of a million star systems will occur. It is not the speed of our computers that facilitates this promise, but the rapid rate of its increase.

As example, the SETI Institute is currently using its own antennas – the Allen Telescope Array, situated in the Cascade Mountains of Northern California – to search 20,000 nearby, red dwarf star systems for signals, and the Breakthrough Listen initiative of the University of California intends to eventually reconnoiter a million star systems. These are both searches that are orders-of-magnitude more ambitious than previous efforts.

In addition, the Allen Telescope Array has been used to examine unusual objects, such as Tabby's star, mentioned above, as well as the TRAPPIST 1 system: a red dwarf star known to have seven orbiting planets all similar in size to Earth.

TRAPPIST 1 is an especially interesting system, both because of its properties and the opportunity it affords for a "smarter" SETI search. At least three (and perhaps more) of the seven planets in this system could have environments conducive to biology. That means that if life has sprung up on any of these worlds, it has undoubtedly migrated to some (or all) of the others. Even bacteria could manage a pilgrimage from one planet to another given the fact that these worlds are so close together (typically separated by a million miles, or only 3 percent the distance between Earth and Mars). Microbes could hitchhike on rock kicked up by incoming meteors, and infect neighboring worlds. If there's intelligence on any of these planets, it's safe to say that it will eventually carpet most, if not all, of the remainder. TRAPPIST 1 offers not only multiple worlds on which biology could arise, but the opportunity for a multi-planet ecosystem.

This latter possibility has inspired an unusual experiment. When two of the TRAPPIST 1 planets are known to line up as seen from Earth, then the Allen Telescope Array is switched on to observe the system. In this arrangement, we are looking down the planet-to-planet communication channel between these worlds. Any rise in cosmic static would indicate the presence of intelligence.

This is the type of experiment that, even five years ago, could not have been done – simply because we lacked the astronomical knowledge that makes it feasible.

In addition, the SETI Institute has begun a project to search for very short flashes of laser light coming from the stars. What distinguishes this effort from other so-called "optical SETI" experiments is that, for relatively little investment, it should be possible to search the entire night sky, all the time, albeit at relatively low sensitivity. This is a very new development, and one that might permit the detection of societies that are not relentlessly targeting Earth with signals.

Funding and public benefit

No one knows when – or even if – we will find life beyond Earth. As noted, most researchers, including those at NASA, think that such a discovery is imminent, within the lifetime of today's millennials.

However, discovery is dependent on funding, and for SETI this is a crippling bottleneck. Until the early 1990s, there was an ambitious NASA SETI effort, conducted at the Ames Research Center and the Jet Propulsion Laboratory. The annual budget, at its peak, was $10 million. Today, excepting a grant to the University of California at Berkeley SETI group by Russian billionaire Yuri Milner, all SETI is funded by donations from the American public. While NASA's budget for solar system exploration is about $1.5 billion, the efforts by the SETI Institute to find sentient life is funded at a level that is two thousand times less. This is despite the considerable public and academic interest in the question being addressed. The total number of people world-wide engaged in SETI is no more than twenty.

The discovery of intelligent life would undoubtedly have a profound impact on society, and indeed, numerous scholarly panels and publications have attempted to gauge what this might be. An informal poll of science journalists by the present author asking how they would rate such a discovery resulted in a unanimous response that this would be "the biggest news story of all time." This despite the fact that whatever intelligence is found will likely be hundreds of light-years distant or more. Conversation, in any normal sense, will not be possible; the communication will be effectively one-way. That needn't diminish its appeal: the writings of the classical Greeks and Romans have taken millennia to reach us. They are still interesting.

But there are benefits to SETI that are tangible and worthy even before, or without, a discovery. Young people are invariably captivated by "aliens" – an interest similar to, and as universal as, their fascination with dinosaurs. Searching for intelligence in space is an effective hook to stimulate their interest in science. This is not hyperbole. The National Academy of Sciences has recognized that a large fraction of those who eventually choose science as a career have done so because of the fictional depiction of science in film and on TV. And much of this programming centers on the existence of beings elsewhere.

Aside from its appeal to young people, the subject of SETI strongly interests the general public. Unlike much modern research, the ideas of SETI are easily comprehended by the non-specialist. It is accessible in a way that other projects are not. The hunt for the Higgs boson was important and expensive. But few people understood the quest or its significance.

SETI is exploration. Unlike much science, its premise can't be falsified. We can't prove that the aliens aren't out there. Like Captain James Cook, we sail the seas of the cosmos with the hope of discovering something new. Despite this uncertainty, SETI has benefits that are tangible and worthy before – or even without – a discovered signal: namely, interesting the public in science, and schooling them in scientific thinking.

The United States exists because of exploration. We, of all nations, should know its value.